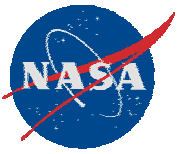


Photoelectrochemical Water Splitting for Hydrogen Production Using Multiple Bandgap Combination of Thin Film Photovoltaic-Cell and Photocatalyst

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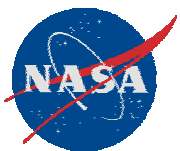
Start Date = December 2002

Planned Completion = September 2006



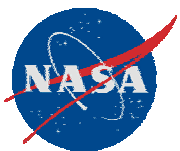
Outline

- Research Goals and Objectives
- Relevance to Current State-of-the-Art
- Schedule and Deliverables
- Anticipated Technology End Use
- Accomplishments and Results
- Future Plans



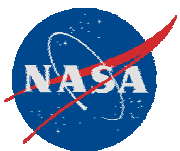
Research Goals and Objectives

- To develop efficient and economic PEC cells for production of highly pure hydrogen and oxygen in the requisite proportion by water splitting using multiple bandgap combination of thin-film photovoltaic-cell and photocatalyst.



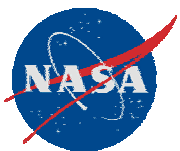
Current State-of-the-Art

- Presently efficient photoelectrochemical (PEC) cells are too expensive (III-V) while cheaper cells are not efficient (a-Si:H).
- Moreover, the PV cells are in contact with the electrolyte - leading to corrosion problem
- Such PEC setup may have limited stability.



Relevance to Current State-of-the-Art

- The PEC cells developed at FSEC PV Materials Lab will be efficient and economical
- In the FSEC PEC setup, the PV cells are not in contact with the electrolyte – problem of corrosion is minimized.
- RuS_2 and $\text{Ru}_{0.99}\text{Fe}_{0.01}\text{S}_2$ anodes which are in contact with the electrolyte are highly stable, even more stable than RuO_2 and therefore, the PEC setup will last long.



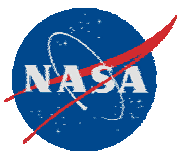
Schedule and Deliverables

- **Schedule**

- Nov 2005 – Mar 2006: Develop CIGS2/CdS thin film PV cells on ITO/MoS₂ and CdS/CdTe cells on ZnTe:Cu transparent conducting back layers.
- Apr 2006 – Sep 2006: Develop Ru_{0.99}Fe_{0.01}S₂ photoanodes and PEC setup to achieve PEC efficiency of >8%.

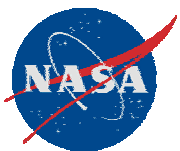
- **Deliverables**

- 1st Six Months: Six Monthly Report (March 2006)
- 2nd Six Months: Annual Report (September 2006)



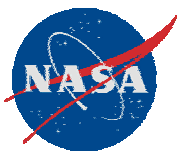
Anticipated Technology End Use

- Highly pure hydrogen and oxygen can be obtained in requisite amounts
- Can be useful in space shuttle and space missions.
- Can be useful in the launch facility.
- Can be used in fuel cells and automobile applications.



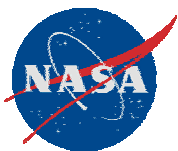
Accomplishments and Results

- FSEC PV Materials Lab has been working on PEC water splitting for the last 6 years.
- PEC efficiency in 2002 – 1.99% with CIGS2/CdS thin film PV cell as cathode and RuO_2 anode.
- New PEC setup with multiple bandgap tandem of PV cells, photoanode for oxygen generation and platinum for hydrogen generation was designed and developed.



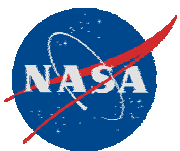
Accomplishments and Results

- Platinum, RuO_2 , RuS_2 and $\text{Ru}_{0.99}\text{Fe}_{0.01}\text{S}_2$ anodes were developed and tested for efficient oxygen generation.
- PEC efficiency 2003 – 4.29% (Two CIGS2/CdS thin film PV cells in series, RuO_2 anode and platinum cathode)
- PEC efficiency 2004 – 5.25% (two CdTe thin film PV cells, RuS_2 anode and platinum cathode)



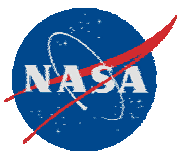
Accomplishments and Results contd.

- Electrolyte concentration was increased to reduce the series resistance.
- PEC efficiency May 2005 – 6.76% (two CdTe thin film PV cells, RuS_2 anode and platinum cathode)
- PEC efficiency October 2005 - >7% (two CIGS2/CdS PV cells, RuS_2 anode and platinum cathode)



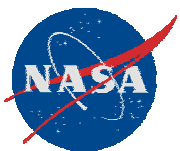
Future Plans

- Develop PV cell on transparent conducting back layers.
 - CdS/CdTe superstrate PV cells on ZnTe:Cu back contact layer and CIGS₂/CdS thin film PV cells on ITO/MoS₂ back contact.
- Make infrared photons not absorbed at the PV cell incident on Ru_{0.99}Fe_{0.01}S₂ photoanode to reduce overpotential required for oxygen evolution.



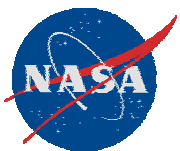
Future Plans

- With the facilities developed along with the knowledge and experience gained from NASA Hydrogen project, it is expected to achieve PEC efficiency $>8\%$ by September 2006.
- This will be an important milestone for practical applications.



Acknowledgements

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Students Supported

- Mr. Anant H. Jahagirdar and Mr. Upendra S. Avachat were supported for their Ph.D. and Master's program respectively.
- Mr. Avachat graduated in summer 2005
- Mr. Jahagirdar will be defending his Ph.D. thesis on November 4, 2005.